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ICE OR LIQUID WATER IN THE MARTIAN REGOLITH? MORPHOLOGIC INDICATORS FROM RAMPART CRATERS; P. J. Mouginis-Mark, Planetary Geosciences Division, Hawaii Institute of Geophysics, University of Hawaii, Honolulu, HI 96822*

Introduction: At the recent Lunar and Planetary Institute's Special MECA Session on geomorphic indicators of martian volatiles (March 1986), it became clear that considerable differences of opinion exist regarding the physical state (or even total absence) of the volatiles within the martian regolith that were responsible for the formation of the rampart crater lobate ejecta flows. Possible forms that this fluidizing medium might take include water ice or liquid water within the target material (1-4), or atmospheric gases interacting with suitable particle sizes within the ejecta curtain (5). Because rampart craters are distributed planet-wide, and occur in regional settings where both liquid water or water ice might be expected to occur (based on the distribution of channels and periglacial landforms) it has long been realised that the correct interpretation of crater morphology would provide the capability to document the spatial distribution and physical state of near-surface volatiles around the planet (cf. 1-4). Recognition of the correct volatile phase would have implications not only for the mode of formation of crater ejecta deposits, but also for other geomorphic processes such as channel network formation and terrain softening. This abstract reviews previously published interpretations on this subject, and considers some of the morphologic features that may be recognizable from the Viking Orbiter images, in an attempt to help resolve this unknown condition of the regolith and provide constraints on the global distribution of volatiles on Mars.

Global Observations:

Early analysis of martian craters (6) drew attention to the numerous craters that possess central peaks with summit pits. These pits are not associated with all fresh rampart craters of a given diameter, and led to the suggestion that the pits were formed by explosive decompression of strata containing subsurface volatiles. Such a situation suggested that in addition to the effects of the volatiles that created the lobate ejecta deposits, volatiles of another phase (possible liquid water as opposed to water ice) might be present. Circumstantial evidence from the analysis of craters (7) and volcanic landforms (8) in the Elysium Planitia region may support this interpretation, since an unusally large number of craters in this region possess pitted central peaks, possibly indicating that liquid water existed close to the surface as a result of a higher than usual thermal gradient.

Johansen (3) and recently Kragel (9) have suggested that the presence or absence of a distal ridge on an ejecta flow may be an indicator of water (ridge present) or ice (ridge absent) within the target material. Although there is a predominance of ridged craters at low latitudes and ridge-less craters at high latitudes (9) no corroborating models for ejecta emplacement, or theoretical or experimental data, were presented by these investigators to support their hypothesis that this difference in morphology was indeed associated with the physical state of water within the target.

Ejecta lobe thickness appears to be limited by some physical aspect of the deposit, inferred to be the maximum shear strength of the fluidized medium (10). No global study has been made of this variation in the upper limit for ejecta thickness, but the value appears to be quite uniform. For example, studies of craters on ridged plains materials between 40°S and 30°N and found no appreciable difference in the surface area (and, by inference, ejecta thickness) for a range of altitudes between +9 km to -2 km (11). This situation was felt to imply that the viscosity (and, hence, degree of ejecta fluidization) may have been constant for cratering events over a wide geographic area for an appreciable amount of martian history.

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WATER OR ICE ON MARS?
Mouginis-Mark, P.J.

There are few close correlations between crater morphologies and target materials, but craters with two concentric ejecta lobes are most numerous in Acidalia and Utopia Planitia (two areas which have been independently identified as probable areas with periglacial landforms; 12). There also appears to be little variation in crater morphology as a function of age (and thus possible evolving atmospheric conditions on Mars). Craters that are apparently very young (inferred to be young due to the preservation of ejecta rays) still possess the same basic form of ejecta morphology as older craters on the same terrains (13).

Because there does not appear to be any strong morphological difference between the individual lobes associated with craters in the 5 - 10 km diameter range and craters in the 30 - 35 km diameter range, it is likely that the fluidizing medium and viscosity of these deposits was similar. Such an idea is borne out by the linear relationship between ejecta area vs. crater diameter curves (for craters 6 - 35 km in diameter; 10). This observation in turn would imply that no appreciable change in volatile state or concentration existed at the time of crater formation for ejecta originating at shallow depths (small diameter craters) and greater depths (large crater diameters).

Experimental Models:

Wohletz and Sheridan (14) suggested that terraced deposits seen on certain ejecta blankets resulted from surges in the emplacement of the ejecta as target water explosively vaporized during the impact event. However, their models did not consider the energy requirements to vaporize water ice as opposed to liquid water. Crater ramparts were thought to form when ejecta surges lost the fluidizing vapors and transported particles were deposited en masse.

No rigorous attempts at laboratory simulations of impact events into targets designed to simulate specific martian conditions have so far been attempted. Initial experiments using the Ames Gun have nevertheless shown that the final crater morphology, the break-up of the ejecta curtain into discrete fragments, and the morphology of the secondary deposits depend upon the viscosity of the target medium (15).

Crater Morphology:

While little positive information on volatile state can be gained from regional trends in the distribution of crater morphologies, a few high resolution (20 meter per pixel or better) Viking Orbiter images provide the capability to search for small morphological features that might distinguish between water and ice existing within the target material. For example, grooves on the ejecta lobes of the craters Bamburg (55 km dia.) and Arandas (25 km dia.) indicate that immediately after lobe emplacement, but prior to cessation of ejecta curtain deposition, the lobes had established sufficient physical strength to preserve these "scour marks" in their surface during the passage of the later ejecta materials (12, 16). A similar effects is also observed where pre-existing obstacles have created pressure ridges within the ejecta lobe on the crater-ward side of the obstacle. It appears unlikely that a very fluid, water-rich ejecta could retain these features after their formation, suggesting that ice might be a more acceptable target volatile.

Few examples of small-scale outflow of water can be seen in even the highest resolution (better than 20 meter per pixel) Viking Orbiter images. Some of the rare exceptions are the channel networks on the rim of Schiaparelli Basin (17), channels on the inner walls and abnormally smooth terrain within the ejecta blanket of Bamburg (16) and previously

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WATER OR ICE ON MARS?
Mouginis-Mark, P.J.

undocumented channels on the inner walls of crater Cerruli. Were liquid water to be more commonly present within ejecta blankets at the time of their emplacement, deposits associated with seepage of water from the ejecta lobes are expected to be more frequently observable in the Viking images.

Summary and Speculations:

The absence of remobilized materials as a consequence of water sapping from the emplaced ejecta, and the formation (and preservation) of scour marks and pressure ridges within the still-forming ejecta blanket, suggest that the ejecta possessed appreciable mechanical strength at the time of emplacement. Numerical models would be needed to determine the effects of different volumeric amounts of liquid water versus water ice entrained within the ejecta, but these observations appear at this time to favor ground ice as the physical state for the fluidizing material responsible for creating the rampart crater lobes.

Boyce (2) suggested that in some regions of Mars, crater morphology may reflect a layer of water-rich material underlying an ice-rich permafrost. Such a situation might be responsible for the formation of the twin lobed craters, and thus mark the point where near-surface ice overlays liquid water. If this hypothesis is valid, it could explain the apparent anomaly whereby the inner, more viscous ejecta lobe was emplaced prior to the outer more fluid lobe (12). It is possible that a reanalysis of the highest resolution Viking Orbiter images could resolve this two-phase model for the regolith if suitable craters were imaged at 10 - 20 meters per pixel.

Clearly, however, these observations of ejecta morphology pertain to a only a few examples of martian craters, rather than comprise a general set of properties for the entire crater population. While these well imaged craters provide an insight into the physical state of the target materials, image resolution may still be insuffcent to identify key landforms. As a result, it is concluded that making the morphology and geochemistry of fresh martian impact craters one of the prime targets for the ultra-high resolution camera and VIMS experiments to be flown on the Mars Observer may be the most appropriate method for identifying the state of volatiles within the regolith at the time of impact.

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